

REMARKS

Claims 1-6, 8-11 and 13-16 are pending in this application. Reconsideration of the rejections in view of these amendments and the following remarks is respectfully requested.

Rejections under 35 USC §103(a)

Claims 1-16 were rejected under 35 U.S.C. §103(a) as being obvious over Iida et al. (EP0962557) in view of Wolf et al (Silicon Processing for the VLSI Era, Volume 1: Process Technology, pp. 8-11, 27-33, 36-72, 124, 139-142, 1986).

In the Office Action, the Examiner alleged that “It would have been obvious . . . to combine Iida et al. with Wolf et al. because Iida et al discloses the quenching of Si ingots pulled with the Cz method to prevent the agglomeration of vacancy point defects in a certain temperature range and Wolf et al. discloses that the quenching in the temperature range of 1421 to 400 °C prevents agglomeration of interstitial vacancy point defects in Cz Si” (Office Action page 3).

The present invention, however, is not directed to the quenching of Si ingots to prevent the agglomeration of vacancy point defects as disclosed by Iida et al, or the quenching to prevent agglomeration of interstitial vacancy point defects in Cz Si as disclosed by Wolf et al.

The present invention provides a method of manufacturing epitaxial wafers by which the thermal stability of oxide precipitates is retained even after the epitaxial step without requiring any additional heat treatment step following silicon single crystal pulling up. Thus epitaxial wafers capable of exhibiting high IG (intrinsic gettering) capability are provided.

Also, the present invention provides a method of manufacturing epitaxial wafers which provides epitaxial wafers allowing formation of a sufficient amount of oxide precipitates upon high temperature heat treatment in the device while preventing the generation of epitaxial layer defects even when they are manufactured from a silicon single crystal grown with nitrogen doping.

Independent claims 1, 2, 4, 5, 7-10, and 12-14 have been amended to recite “wherein the single crystal has an oxygen concentration of not less than 12×10^{17} atoms/cm³ (ASTM ‘79 value).” Claims 3, 6, 11 and 16 have been canceled.

In Iida et al, as shown in paragraph [0013], oxygen concentration in the single crystal is preferably controlled to be 1.0×10^{18} atoms/cm³ (ASTM ‘79 value) or less. In the examples disclosed in Iida et al, oxygen concentration in the single crystal is controlled to be 0.8×10^{18} atoms/cm³. Thus, Iida et al teaches away the recitation “wherein the single crystal has an oxygen concentration of not less than 12×10^{17} atoms/cm³ (ASTM ‘79 value),” as recited in the amended claims.

In order to achieve the object, the present invention increases the density of oxide precipitate in the single crystal by promoting formation and growth of thermally stable oxide precipitate nuclei. Therefore, the present invention is not directed to controlling the pulling rate in order to prevent agglomeration of interstitial and vacancy point defects, which is disclosed. Neither Iida et al nor Wolf et al teaches or suggests a process for increasing the density of oxide precipitate in the single crystal.

The Examiner alleged in the Office Action at page 3, lines 5-6, that, in Wolf et al, “On page 59-61 oxygen in Si is detailed as forming precipitates at approximately 550-800 °C.” This allegation is based on misunderstanding. What is disclosed there is that oxygen donor can be formed in the temperature range

of 550-800 °C. The formation of oxygen donor is a phenomenon where an oxygen atom gives an electron receiving a certain energy, which is completely different from the oxygen precipitate in the present invention. Moreover, the present invention does not recite the cooling condition in the low temperature area of 550-800 °C, which is disclosed in Wolf et al.

For at least these reasons, claims 1, 2, 4, 5, 7-10, and 12-14 patentably distinguish over Iida et al and Wolf et al.

Moreover, claims 1, 2, 4 and 5 are directed to a method of manufacturing a silicon single crystal not nitrogen doped while Iida et al discloses a method of manufacturing a nitrogen-doped silicon single crystal. Formation of oxide precipitate nuclei in a single crystal is significantly different between a nitrogen-doped single crystal and a single crystal not nitrogen-doped. Therefore, the process disclosed in Iida et al is not applicable to a silicon single crystal not nitrogen-doped.

Claims 1, 2, 4 and 5 recite “a cooling rate of not less than 7.3 °C/min in the single crystal temperature range of 1200-1050°C.” Iida et al discloses a cooling rate of 3.5 °C/min or less from 1150 to 1080°C. Nothing in Iida teaches or suggests “a cooling rate of not less than 7.3 °C/min in the single crystal temperature range of 1200-1050°C.”

Intrinsic gettering achieved by claims 1, 2, 4 and 5 is not obtained using the cooling rate disclosed by Iida et al.

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Also, claims 8, 9, 13 and 14 are directed to a method of manufacturing a silicon single crystal doped with 1×10^{12} atoms/cm³ to 1×10^{14} atoms/cm³ of nitrogen. These claims recite “cooling the silicon single crystal **at a cooling rate of not more than 1.2 °C/min** in the single crystal temperature range of **1000-850 °C**,” which is not taught or suggested by these references. This slow cooling rate in the temperature range is important to obtain a sufficient density of oxide precipitates.

Also, claims 10 and 15 are directed to a method of manufacturing a silicon single crystal doped with 5×10^{13} atoms/cm³ to 1×10^{16} atoms/cm³ of nitrogen. These claims recite “**a cooling rate of not less than 6.5 °C/min** in the single crystal temperature range of **1150-800 °C**” which is not taught or suggested by the cited references. Without this rapid cooling, too many thermally stable oxide precipitates are formed resulting in epitaxial defects in the epitaxial growth process.

In view of the aforementioned amendments and accompanying remarks, claims, as amended, are in condition for allowance, which action, at an early date, is requested.

If, for any reason, it is felt that this application is not now in condition for allowance, the Examiner is requested to contact Applicants’ undersigned attorney at the telephone number indicated below to arrange for an interview to expedite the disposition of this case.

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In the event that this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. Please charge any fees for such an extension of time and any other fees which may be due with respect to this paper, to Deposit Account No. 01-2340.

Respectfully submitted,

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